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Face mask application as a tool to diminish the particulate matter mediated heavy metal exposure among citizens of Lucknow, India

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ABSTRACT

Traffic related fine particulate emissions, enriched in metal contents, are directly linked to respiratory disorders in human subjects. In view of the growing traffic related emissions in India, the present study was undertaken to estimate the heavy metal exposure among non-occupationally exposed two vehicle riders of Lucknow City and related health effects via application of face masks (FMs) fitted with cellulose nitrate filters and measuring the peak respiratory flow rate (PEFR). Carefully selected 200 volunteers (asymptomatic n = 154 and symptomatic n = 46) were advised to use FMs during their deriving time for 30 days and PEFR test was conducted on each subject at the beginning, i.e. 0 day, and at end of the study period, i.e. 30 days. On completion of the prescribed study period, filters from the used FMs were collected, acid leached and analyzed for Fe, Mn, Cu, Zn, Pb, Ni, Cr and Cd. Asymptomatic and symptomatic subject groups were further divided into two age groups of 15–40 years and 41–68. Pb, Cu and Cd were significantly higher in lower age group (15–40) of symptomatic group and Cr was in asymptomatic group. Negative associations were observed between metals viz. Pb ($r = -0.39$, $p<0.001$), Cd ($r = -0.26$, $p<0.001$), Fe ($r = -0.37$, $p<0.001$), Mn ($r = -0.15$, $p<0.05$) and the lung functioning. 30 days PEFR of all subjects were higher by nearly 10% than 0 day in all 200 samples irrespective of age and symptomatic nature of the subject. The improvement could also be due to metals and other organic species, not analyzed herein. Nevertheless the results indicate that FM usage has a role to play for immediate, if not ultimate, improvement in public health and need further studies.

1. Introduction

In recent years, heavy metals associated with respirable suspended particulate matter (RSPM, <10 micron size) present in the urban environment, have received much attention due to their various direct toxic effects on human health via their inhalation. Among different anthropogenic sources vehicular emission contributes significantly to the RSPM and gaseous species load in an urban environment. These emissions not only arise due to fossil fuel burning but also contain the particles arising out of wear and tear of tyres, other parts of vehicles (Mejstic et al., 2009). The abrasion of catalytic convertors installed in vehicles releases the transition metals like Pd, Pt and Rh into the environment which have very serious health effect (Limbeck et al., 2004). In addition to direct inhalation during their emission the re suspension of the fine particles deposited on the roads and road sides back into the atmosphere, by winds or vehicular turbulence, increases the exposure time and hence the chances of affecting human health in the region (Tandon et al 2008; Thorpe and Harrison, 2008). The ill effects of the fine particles are well documented in the literature and being studied in depth in tune with growing number of vehicles, technology, knowledge and concerns about human life (Balmes, 2009; Sunyer, 2009 and references therein).

The effects of traffic related emission in human subjects can be well estimated through lung function test (Trenga et al., 2006; Sunyer, 2009). The test is not only to evaluate lung capacity/any bronchial obstruction among subjects but also tell about the cardio respiratory morbidity and mortality, chances of occurrence of chronic obstructive pulmonary diseases (COPD). The coherence between the primary data on deposition and accumulation of fine particles in human airways and lungs and the resulting lung inflation and stress adds to the validity of the test (Pope and Dockery, 2006). The association between traffic related emissions and incidences of asthama is well documented in

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literature (Balmes, 2009 and references therein). Peak Expiratory Flow Rate (PEFR) test is frequently used to assess the effects in particular on lungs (most vital part of body) of atmospheric emissions on human subjects (Bellia et al., 2003; Ingle et al., 2005; Tang et al., 2007). The relationship between fine pollutants and lung function, principally PEFR, is mostly consistent despite the differences in definitions of outcome measurements and statistical methods used to model the relationship between air pollution and health (Trenga et al., 2006). There exist an inverse relationship between PEFR and the particulate matter exposure levels i.e. with the increment in PM leads to decrease in the PEFR (Hong et al., 2007). The persons deriving on the road, staying near the roads, children and the symptomatic person with prior disease history) are more prone to decrement in the PEFR values due exposure to traffic related emissions (Trenga et al., 2006; Tang et al., 2007; Balmes, 2009). PEFR decrease on exposure to pollution could be due to 1) the increased levels of RSPM and 2) increased levels of metal(s) and organic compound (Hong et al., 2007 and references therein). The transition metals primarily lead, copper, cadmium, chromium, iron, manganese, nickel, zinc, Platinum, pladimium and Rohodium are the important constituent of vehicular emission along with the volatile organic compounds and other poly aromatic hydrocarbons and increases the toxicity potential of RSPM (Schlesinger et al., 2006). Metal affects the human physiological system directly as well as through their role in generation of reactive oxygen species in the body (Li et al., 2008). The lung function test shows a negative correlation with the increased levels of RSPM in atmosphere (Tang et al., 2007).

Lucknow City situated in the indo-gangetic plains of India consistently encounters the increased levels of RSPM well above the standard limits. Central pollution control board (CPCB, 2007) reported RSPM levels equal to 185–207 μg/m^3 in the city during 2005. Increased number of vehicles particularly, two vehicles in and around city remains the major cause of concern for air pollution. Lucknow, the capital city of most populated state of Uttar Pradesh (U.P.) in India, has augmented vehicular population to many folds during the last 10 years and has more population of two wheelers (>70%) than three and four wheelers (I.I.T.R., 2008). The congested roads, heavy population density adds to the exposure time and levels of traffic related emissions to road users, in particular to the two vehicle riders. The habit of not wearing helmets by these riders in the city makes the problem more complicated. Previous studies done elsewhere in India indicate the respiratory impairment in the subjects due to exposure to traffic related emissions (Ingle et al., 2005; Chattopadhyaay et al., 2007). They observed the reduced lung functioning among the vehicular pollution affected subjects. In view of the high traffic related emissions and their adverse impact on human health, we planned the present study to investigate the metal exposure levels through direct inhalation of fine particles in the selected subjects deriving two vehicle in Lucknow City and to evaluate the correlation between metal exposure and the lung functioning through PEFR test. Full face mask (FM) fitted with filter papers were used for collection of PM during the deriving hours i.e. exposed time of subject for 30 days. Based on the finding we propose the usage of FMs by two vehicle riders as a preventive tool against hazardous metallic air pollutants. This approach may also be useful to identify and promote strategies that might provide immediate improvements to public health.

2. Sampling and analytical details

Present study on estimation of metal exposure through application of FMs and improvement in PEFR of the studied subjects was conducted in Lucknow City (26°52′N and 80°56′E) located in the heart of Indo gangetic plains of India. Lucknow encompasses a total area of about 310 square kilometer and has population of nearly 2.62 million (as on 2008) with density of 1081 per square kilometer. In the recent year city has encountered unprecedented growth in traffic density (World Gazetteer, 2008; I.I.T.R., 2008), more so for two vehicles resulting in high levels of vehicular emissions and related health problems. The average climate regime is hot summer and severe cold winter with an average rainfall of 900 mm/year.

More than one thousand full face masks (FMs) fitted with cellulose nitrate filter were distributed among the two wheelers riders (subjects) during the study period (November 2004 to January 2005). The user friendly features like cloth faced elastic, straps of proper length and strength to obtain a comfortable fit, method of attachment i.e. stitched, easy for donning and doffing, individual packaging and durability etc. (Utell and Frampton, 2000; Blank, 2005) as well as their local availability of these FMs were the criterion for their selection over the other two types i.e. disposable particle mask and Half and quarter mask respirators with reusable filter pad. Pre-desiccated and pre-weighed Cellulose nitrate filters (Omni brand, procured locally) were used in FMs for collection of particulates matter during the usage of FMs. Only two wheeler riders were taken as test subjects due to their high vulnerability to the exposure/inhalation of RSPM either directly emitted from vehicles or re suspended on the roads in urban environment of Lucknow City. The rational in distribution of FM to the subjects included age and health of the subject, area/route and frequency of travelling. The due care was taken so as to include 1) the subject of different age group ranging from the permissible age for deriving in India i.e. 18 onwards, 2) symptomatic (having previous history of respiratory disorders) and asymptomatic (with no respiratory problems) and 3) the representation from the whole city environment as the nature of traffic (scooter, motor bikes) and traffic congestion vary widely across the city. The selection of the subjects was done purely on voluntary basis and consent was taken on a survey performa along with the relevant details desired for the present study (see the Supplementary material). The symptomatic subjects volunteered in the study were having the disease like asthma, dust allergy, coughing and bronchitial problems etc. The volunteered subjects were requested to use the FMs for 30 days period during their deriving time and to maintain the record of their deriving hours to the best of their honesty. They particularly, the symptomatic subjects were also advised to remove the FM immediately if they feel suffocation and uneasiness in breathing. During the period of study we tried to meet as many subjects as possible to check the proper usage of the FMs and to note and solve the problems encountered by them in using FMs. In spite of our best efforts we could get back only 300 FMs at the end of study period. Others have either disappeared or did not used FMs continuously or did not maintain the record of deriving or spoiled the filters fitted in FMs. Out of these 300 subjects, we could select only 200 subject who have kept the FMs and filters fitted in them in proper state and maintained the record of deriving/FM's usage hours as well could made us to trust on FM's usage. The filter papers with deposited RSPM were taken back after the 30 days study period and labeled during the collection process in the field and stored in the plastic capped vial for safe transportation and storage in laboratory for further analysis. These filters were again desiccated and weighed to calculate the amount of RSPM deposited during the FM usage of 30 days.

Peak Expiratory Flow Rate (PEFR) test of each volunteer was performed in the beginning of the study using a Peak flow meter Instrument (Clement Clarke Inc, USA) to evaluate lung capacity/any bronchial obstruction among the subjects. Each time test was performed thrice on each volunteer without a nose clip, allowing for sufficient rest between repetitions and the average value are reported. PEFR test at the end of 30 days period of study was conducted on the finally short listed 200 subjects as stated above paragraph. The instrument was pre calibrated in the toxicological laboratory in ITRC, Lucknow. We followed general considerations as proposed by Miller et al. (2005) for performing lung function test on a subject.